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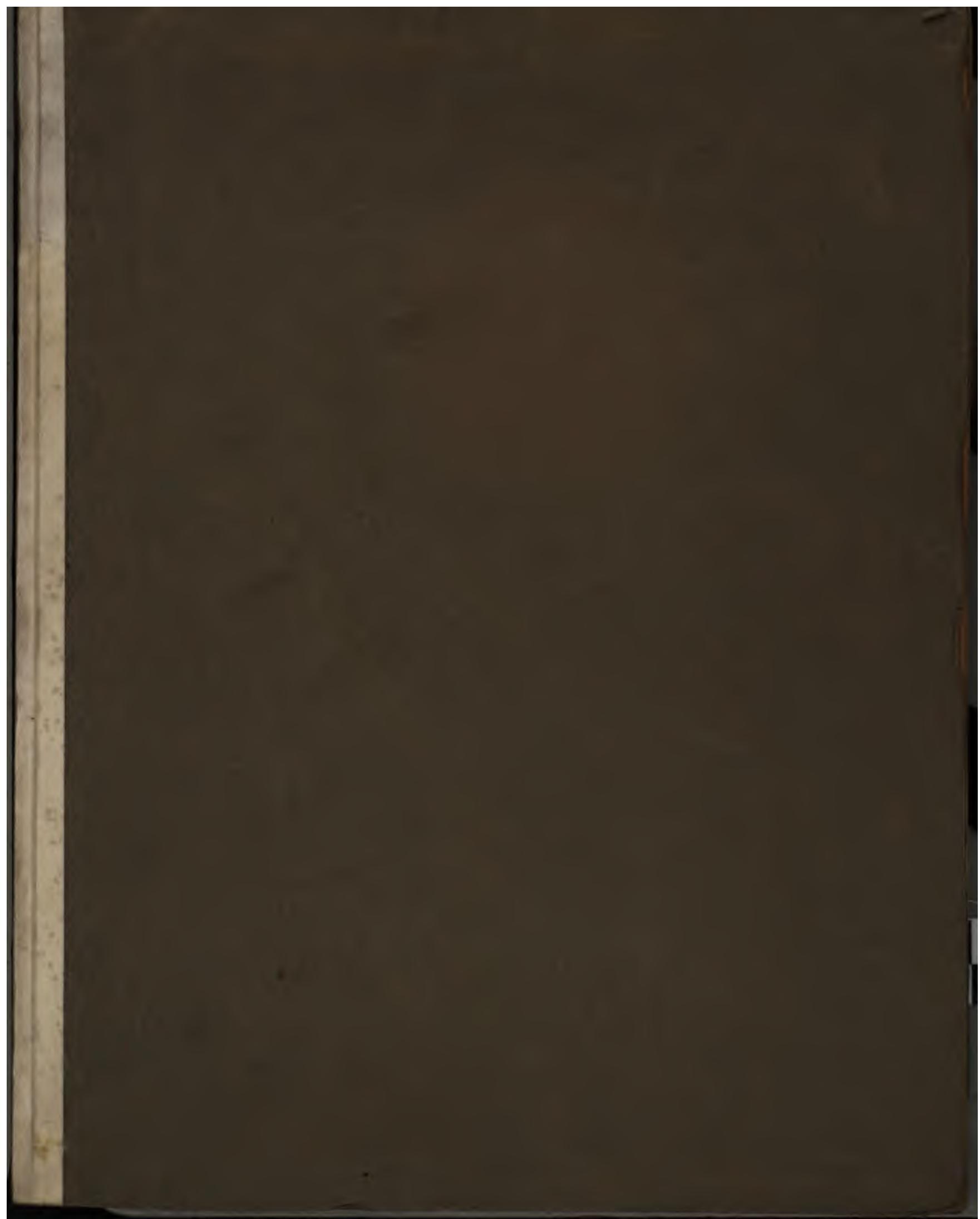
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OBSERVATIONS  
ON  
THE PRINCIPLE OF VITAL AFFINITY.

PART II.

BY

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III.—*Observations on the Principle of Vital Affinity, as illustrated by recent discoveries in Organic Chemistry.* By WILLIAM PULTENEY ALISON, M.D., F.R.S.E., Professor of the Practice of Medicine in the University of Edinburgh.

(Read 1st and 15th February 1847.)

#### PART II.

It may be remembered that, in the paper formerly laid before this Society on this subject, I endeavoured to establish the principle still disputed by some physiologists, that the laws which regulate the chemical relations, as well as those which regulate the visible movements of the particles of matter, undergo a certain determinate modification or change in living bodies, which is essential to the commencement and to the maintenance of the organization of those bodies; and farther, that I undertook the task of attempting to deduce, from the numerous but somewhat discordant experiments and observations lately made on the subject, certain inferences which appear to be well ascertained, although not generally admitted, as to the essential nature of this change, *i. e.*, as to laws which regulate those chemical actions which are peculiar to the state of life, and essential to the maintenance of organization, both in vegetables and animals.

In confirmation of my statement of the general principle of Vital Affinity, as distinguished from simply chemical affinities, I have much satisfaction in quoting two sentences from the last edition of LIEBIG's "Animal Chemistry." Some of the statements of general principles made by this author, seem to me open to objection, and some I do not profess to understand; but the following is simple and precise; and, considering the authority of LIEBIG as a chemist, may, I think, be held nearly decisive as to the soundness of the principle. "A fundamental error, committed by some physiologists is, that they suppose the chemical and physical forces alone, or in combination with anatomy, sufficient to explain the phenomena of vitality. It is, indeed, difficult to understand how the chemist, who is intimately acquainted with chemical forces, should recognise in the living body the existence of *new laws*, of new causes, while the physiologist, who is little or not at all familiar with the action and nature of chemical and physical forces, should think himself ready to explain the same processes with the aid of the laws of inorganic nature alone."—*Animal Chemistry (third edition, p. 252.)*

The first and most fundamental of these general principles (likewise considered in my former paper) is the power of vegetable life, under the influence of light, to decompose the carbonic acid existing in the atmosphere,—set the oxygen free, fix the carbon, and form with it and the elements of water, starch, sugar, gum, and the analogous compounds. Our knowledge of this power, of the effects

which result from it, and of the period when it must have been first exerted on the earth's surface, enables us to assert with confidence, that by means of it, the whole organised creation has been, as DUMAS expresses it, the offspring of the air; and that it was by enabling the rays of the sun to excite this action in certain particles of matter, existing in the atmosphere, but destined to be either the first specimens, or the first germs of vegetable life, that "a beneficent God," to use the striking expression of LAVOISIER, "has strewed the surface of the earth, first with organized structures, and then with sensation and thought."

In proceeding farther to inquire into the laws of Vital Affinity, we must always keep in mind the general arrangement or classification, long ago made by Dr PROUT, of all the organic compounds, of which any organized structures, vegetable or animal, are composed, into three groups or classes, the Saccharine or amylaceous, the Oily, and the Albuminous; and the important observation, I believe first made by him, that the food of most animals contains all these compounds, and that no complex animal structure can be maintained without the concurrence of at least two of these kinds of compounds in its food.

I do not think it is going too far to say that we have now a general knowledge of the laws or conditions under which all these compounds are formed in living bodies, taking the starch formed from carbonic acid and water as the foundation of all. But we perceive farther, that that these laws, *varying in different parts of the same structure, and at different times in the same parts*, and being of *transient duration* in all, are liable to an *influence of time and of place*, and in animals to a farther influence of mental changes, which is quite analogous to the vital actions, both of muscular and nervous organs, but is strongly contrasted with the uniformity of the laws that determine the changes of inorganic matter. And if this be so, we may assert that considerable progress has been made, both in establishing and in illustrating the doctrine of vital affinity, as a first principle in physiology.

I. The formation of Oil or Fat in living bodies is, perhaps, that part of the chemical processes there carried on, which is now the best understood, and the study of which gives us the clearest insight into the nature of vital affinities. We need not enter into any of the simply *chemical* questions as to the mode of combination of the fatty acids and bases in the different kinds of fat; it is sufficient for our purpose to observe that they are found very generally, though very variously disposed, in almost all vegetables and animals, and even in the earliest stages of their existence; the store of nourishment contained in the seed and in the egg, containing a proportion of fatty matter. And though there is considerable variety in the different kinds of fat or oil, they all differ from the varieties of starch, by having a much smaller proportion of oxygen, and, of course, a larger proportion

of carbon and hydrogen. The composition of most fats is stated by LIEBIG to be  $C_{12} H_{10} O_1$ ; and we have thus, therefore, another compound formed apparently by vital affinity, indicating a peculiar attraction of the two first elements for one another, and a feeble attraction for oxygen. Indeed, in the composition of wax (one of this family of compounds), as stated by MULDER, the proportion of oxygen is only one equivalent to 24 of carbon; in cholesterine, the proportion of carbon to oxygen is stated as high as 36 to 1; and in many volatile oils, no oxygen has been detected.

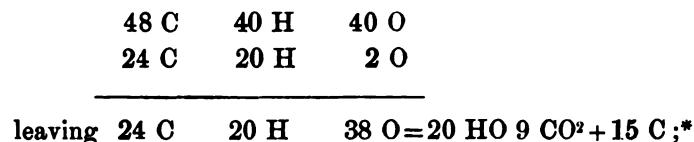
Supposing such a peculiar affinity to act, there is obviously no difficulty (on looking at the numbers indicating the proportions of the elements) in understanding the formation of these compounds out of starch ( $C_{12} H_{10} O_{10}$ ), just as there is none in understanding the formation of starch or sugar (although by an affinity occurring only in living bodies, and which we regard as vital) from carbonic acid and water ( $CO_2 + HO$ ), in living vegetables, where a continual evolution of oxygen attends the growth; particularly if we suppose that the carbonic acid taken in by the leaves and roots, is carried to, and decomposed in, all parts of the plant; the formation of the fatty compounds, is, no doubt, one of the processes by which the oxygen is set free. But in the case of animals, where (with the exception of some of the infusory tribes) there is no evolution of oxygen, the formation of fat from starch presents a difficulty. Yet the numerous observations and experiments of LIEBIG and of CHEVREUL and MILNE-EDWARDS, leave no room for doubt that various animals, fed chiefly on varieties of starch, or bees fed on sugar, form a much larger quantity of fat, oil, or wax, than they have received mixed with their food, and this when they are exhaling no pure oxygen, but, on the contrary, compounds of hydrogen and carbon with oxygen, viz., water and carbonic acid. Indeed, Dr ROBERT THOMSON having ascertained by repeated experiments, that the quantity of butter yielded by cows bears no fixed proportion to the quantity of oleaginous matter contained in their food, varying indeed from one quarter to nearly the whole of the oleaginous ingesta, thinks himself justified in inferring that "the butter cannot be supplied from the oil of the food." (*On the Food of Animals*, p. 156.)

It is quite certain that in this action, in all animal bodies, the greater part of the oxygen of the starch employed must unite with a portion of its carbon and hydrogen, and pass off in the excretions just noticed, leaving the small remainder of the oxygen in combination with the predominant quantities of carbon and hydrogen.

It appears possible, indeed, that *all* the oxygen which must be separated from starch before it can be converted into fat, may be evolved in combination with part of the carbon and hydrogen of the starch, without any constituent of the air taking any part in the process; but the quantity of fat formed would then be small, and it is also possible that the oxygen of the air may be concerned

in the metamorphoses to which starch is liable in a living body ; and as we know the importance of oxygen in maintaining (in one way or other) all vital action, the latter supposition is more probable.

If, *e. g.*, we suppose 4 atoms of starch to yield 2 of fat, we must subtract from



so that on this supposition 15 atoms of carbon are set free, and as these do not appear, they must unite with the oxygen of the air, and take the form of carbonic acid ; and then the fat which appears, together with the water and carbonic acid thrown off, will account for all the elements concerned in the action. In this process, therefore, supposing the quantities of starch taken in, and of fat formed to be as above, 30 equivalents of oxygen must be absorbed ; so that we perceive the use of oxygen in the change, and the necessity of its presence, although the fat formed contains so much less oxygen than the starch.

That this should be the real nature of the change is just what we ought to expect, if, agreeably to the supposition formerly made, the starch taken into the blood of a living animal, is acted on at certain parts of the body by two powers, and divides itself between them, *viz.*, a vital affinity, in which carbon is the chief agent, which leads to the formation of fat, and the simply chemical affinities, exerted chiefly by oxygen (continually taken into the blood), by which, if removed from the living body, we know that it would gradually be resolved into carbonic acid and water. And that this is the real state of the case we are fully assured by a simple but very important observation, *viz.*, attending to the effect of *exercise* on the formation or deposition of fat in the living animal body. As we see by the numbers given above, that a certain amount of oxygen must be absorbed, and a certain quantity of carbonic acid and water, formed by its help, must be excreted, to enable starch to yield oil or fat by the process there represented, we can understand that moderate exercise should favour the change ; but when exercise is carried beyond a very moderate extent, we know that the circulation and respiration being much accelerated, and the quantity of oxygen taken into the living blood being much increased, the effect is, to increase the exhalation of carbonic acid and water, and proportionally to diminish the deposition of fat ; *i. e.*, to give a preponderance to the simply chemical affinities exerted by the oxygen, over the vital affinity, which would tend to the formation of fat.

From this simple fact we may infer, 1. That the vital affinity by which oil is

\* It need hardly be said, that all these numbers are given, not as indicating the exact changes which take place when the organic compounds are formed, but only as illustrating their general nature.

formed from starch, or by which its elements are held together, does not supersede its natural chemical relations, but only adds a new chemical power to those which can operate on it, and allows of a division of the starch between the result of a vital and a simply chemical affinity; and, 2. That the vital action by which fat is formed or maintained, is of no great strength, as compared with the simply chemical affinities to which the same matter is liable; being superseded simply by an increased supply of oxygen. And we cannot doubt that, in this as in other vital chemical processes, the oxygen, although not taken into the organic compound formed, aids its formation materially, by promoting, on the principle of divalent affinity, the other parts of the metamorphoses whereby it is produced. We shall see afterwards the importance of having it established by this simple example, that the oxygen of the air, when taken in full quantity into the blood, is capable of combining, somewhere in the course of the circulation with a part of that carbon and hydrogen, recently absorbed into the blood, which, under a smaller supply of oxygen, would form a living texture; and that the combination of these portions of the ingesta with oxygen, are one source of the excretions.

There are other facts which lead to the same conclusion, as to the affinity by which fat is formed, being more nearly akin than most vital actions to simply chemical affinities; particularly,—

1. The formation of Adipocere, not from starch, but from albumen, after vitality is over, when undergoing decomposition under ground, where there is a full supply of water and but little air, so that the supply of oxygen is less than in ordinary putrefaction, which may be understood thus:—

	C	N	H	O	
	48	6	36	14	= Albumen
Add			12	12	Water
				1	Oxygen
	48	6	48	27	
Subtract 36			30	3	Fat
	12	6	18	24	= Carbonic Acid and Ammonia

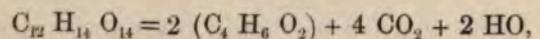
which escape, and the attraction of which for each other, no doubt in part determines the result.

2. Again, in the living body, but in a feeble constitution, along with great emaciation, and a deficient supply of oxygen, a morbid deposition of fat sometimes takes place, in circumstances where it could not have been anticipated, but only in particular parts. Some distinct cases of this kind have lately attracted attention, one in the kidneys, in one form of BRIGHT's disease, another in the liver, as in many phthisical cases, and a third in the atheromatous exudations

so common on the arteries. It may be suspected that in these cases the formation of fat is by an affinity hardly more vital than the formation of adipocere,—in both cases the decomposition of albumen to form the fat, being aided by the simply chemical affinities, of carbon for oxygen, and of hydrogen for azote.

3. The same peculiarity of the attractions by which fat is formed in the animal economy may be admitted in explanation of the more general fact, that in a healthy constitution, when more, particularly of amylaceous, food is taken than is required for the nutrition of the more important textures, and when little oxygen is taken in, the excess always tends to the deposition of fat, which implies that a large portion of the oxygen of that food has gone off as carbonic acid and water.

The process of the formation of oil from starch in the animal body, admits of an instructive comparison with the simply chemical one of the formation of alcohol from the same matter,—at least, from a compound fluid of which starch (first converted into sugar by the kind of fermentation formerly mentioned) is the chief constituent, in fermentation; *e. g.*, the changes in the vinous fermentation of grape-sugar, are represented thus,—



that is, the elements of grape-sugar resolve themselves into two equivalents of alcohol, four of carbonic acid, and two of water. In this case, as in the formation of fat, the starch or sugar is divided into three parts, water, carbonic acid, and a peculiar compound fluid. In both cases, the oxygen of the air is necessary to the commencement, and probably to the continuance, of the process, although in both, the new compound formed contains less oxygen than the starch or sugar from which it is produced. In both cases, a third body is present, and its influence somehow promotes the process, besides the oxygen and the starch, *viz.*, in the one case, yeast, or some kind of ferment, itself in a state of decomposition, which it imparts, without giving up any part of its substance, to the starch or sugar; in the other case, a living cell, composed of gelatin, which is itself undergoing a simultaneous change, by a living process. In both cases, extension of the change takes place, as from a centre, from this third body, through the fluid in which the change commences. In both cases, the compound formed is not stable; and the portions of the starch which go to form it are destined ultimately to follow the same course as those portions which are resolved into carbonic acid and water. In the one case, the compound formed,  $C_2 H_6 O_2$ , contains a less proportion of carbon than any of those which we regard as endowed with strictly vital properties; while, in the other, the compound formed,  $C_{12} H_{14} O_1$ , has the characteristic predominance of carbon. But if we are asked, Why we regard the one as the result of a simply chemical process, and the other of a vital affinity? I apprehend the sufficient answer to be,

that the one is a change which uniformly results when the sugar is exposed to the influence of air, water, and a certain temperature; and is in contact with a substance undergoing some part of that decomposition and chemical change to which living bodies are liable after the phenomena of life are over; whereas the other is not seen, in the presence of those substances, and under those conditions as to air, water, and temperature, in which it here takes place, unless the starch is at the same time in contact with living cells,—*i. e.*, cells forming a part of a body in which the peculiar phenomena of life are then exhibited.\*

II. The next question is as to the formation of the Albuminous, or what have lately been called the Protein, compounds in animal bodies. The late acrimonious dispute as to the existence of Protein, should rather be termed a dispute as to the exact composition of the compound to which MULDER gave that name, and which is thrown down from the solution of either albumen or fibrin, in potash, by acetic acid. Of the precipitate being the same in both cases there is no doubt; and we shall avoid the controversy entirely, by using the term Albuminous Compounds, as Dr PROUT did, instead of the term Protein.

Since it has been clearly ascertained, that the vegetable gluten is identical in composition with the albuminous compounds,—*i. e.*, fibrin, albumen, and casein of animals,—no doubt can exist that the formation of a great part of the albumen found in animal bodies must take place in vegetables; and, I presume, it is also generally agreed that the chief agents in this farther change, beyond the formation of starch and of fat, are sulphur, and ammonia or its elements, taken into the fluids of the vegetable, although it is still doubtful from what sources this ammonia or its elements may be originally derived, and particularly whether, in any circumstances, the azote of the atmosphere is concerned in producing it.

Some experiments recorded by DUMAS,† however, seem to leave no room for doubt, that certain families of plants, in one way or another, fix azote from the air, being found to add largely to that contained in their seeds, when germinating and growing merely in silica and water; and it is by no means ascertained, that this azote passes necessarily into the state of ammonia before it is applied to the nourishment of those vegetables. And the statements of MULDER seem equally conclusive as to the fact, that ammonia may be

\* It is no objection to this statement, that oily matters may, in different cases besides that of adipocere already noticed, be formed from organic compounds in the dead state, *i. e.*, by simply chemical affinities. To establish that the affinity by which it is formed in a living structure is vital, it is not necessary to shew that oil cannot be formed, under any circumstances, by simply chemical laws, but only to assure ourselves, that it cannot be formed by those laws from the substances, and in the circumstances, in which it is continually formed in certain living cells.

† Balance of Organic Nature, p. 77.

formed by the union of azote from the atmosphere with hydrogen from water, whenever another substance, exerting an attraction for the oxygen of the water, is present.—(*Chemistry of Vegetable and Animal Physiology*, p. 149, *et seq.*) Now, as carbonic acid and water form starch, or its allied compounds, in the living vegetable, by the attraction of carbon for the elements of water, to the exclusion of oxygen; and as the starch then forms oil, by the attraction of the carbon to hydrogen, to the exclusion of great part of the remaining oxygen; so, on the introduction of ammonia, or its elements in a state fit for entering into new combinations, into the scene of those metamorphoses, it is only in accordance with what we know of the nature of these vital affinities, to suppose that the carbon may attach to itself the elements of this ammonia, to the exclusion of the elements of water and of oxygen, matters which are known to be continually thrown off by vegetables, during the continuance of these vital processes. Thus we have the elements of starch, 48 C, 40 H, 40 O *plus* the elements of ammonia, 6 N, 18 H, = 48 C, 6 N, 58 H, 40 O = 48 C, 6 N, 36 H, 14 O (the elements of albumen) *plus* 22 H O + 4 O, a considerable quantity of the water, and a small quantity of the oxygen, which are continually exhaled by the plant.

Thus, during the whole process of the formation of organic compounds in the vegetable, we see that the vital affinities shew themselves by the attractions of Carbon, first for the elements of water in preference to oxygen, then, either for the hydrogen of those elements, in preference to the oxygen, or for the elements of water, with an excess of hydrogen, along with those of ammonia; and thus, by these peculiarities of attraction of Carbon, for the elements of water, for hydrogen, and for azote,—to the more or less complete exclusion of oxygen,—we see that the essential materials of all organized matters may be easily formed,\* while water and oxygen, the known excretions of vegetables, only escape.

The point at this moment most disputed, and the settlement of which is most essential to the precise comprehension of the nature of vital affinities, is, Whether there is any formation of albuminous matter in *animal* bodies? and it is obvious, that there is a difficulty in regard to its formation from starch, just similar to that which was stated as to the formation of oil in the animal body, because we see no evolution of oxygen; but it is also certain that this may be got over, precisely in like manner as in the former case, by supposing—what is quite in accordance with known facts—that a considerable absorption of the oxygen of the air attends the process, and that, with its help, a large portion of the carbon

\* This may be shortly stated thus  $\text{CO}_2 + \text{HO}$  = Carbonic acid and water. From this is formed,  
 $\text{C} + \text{H} + \text{O}$  = Sugar, oxygen going off. From this,  
 $\text{C}_{48} \text{H}_{40} \text{O}_{40}$  = Starch, water going off. From this, either  
 $\text{C}_{48} \text{H}_{40} \text{O}_4$  = Fat, oxygen going off. Or,  
 $\text{C}_{48} \text{N}_6 \text{H}_{36} \text{O}_{14}$  = Albumen, ammonia being added, and water and  
a little oxygen going off.

and hydrogen are thrown off in carbonic acid and water. Thus, supposing a large quantity of starch, 60 C, 50 H, 50 O, to unite with a small quantity of ammonia, we have

	C	N	H	O	
	60	6	68	50	and adding 20 of oxygen,
we have	60	6	68	70	= 48 C, 6 N, 36 H, 14 O,

(the elements of albumen) + 32 HO + 12 CO<sub>2</sub>, the water and carbonic acid which escape. Or, adding an equivalent of oil, we may have

	C	N	H	O	
	48	...	40	40	Starch.
Add	12	...	10	1	Oil.
	...	6	18	...	Ammonia.
Subtract	60	6	68	41	
	48	6	36	14	Albumen.
	12	...	32	27	Adding 29 oxygen,

we get 12 CO<sub>2</sub> + 32 HO carbonic acid and water.

It is certain, therefore, that if the elements of ammonia can be set free in the primæ viae of an animal, starch absorbed from thence, with or without the addition of oil, may be converted into albumen in its blood, without any other matter being thrown off than the water and carbonic acid, which undoubtedly escape from every animal. If this be so, we have here another division of the elements of the ingesta, between substances exerting a vital and a simply chemical affinity for them, and another formation of part of the excretions, by the help of the oxygen of the air, from matters recently absorbed, and which aid in the nourishment of the animal. But whether this is a process that actually goes on in the animal economy, or whether all the albuminous compounds of animal bodies have passed into them, directly or indirectly (but ready formed), from vegetables, is the point at this moment the most important to be ascertained.

As it is obvious that the albuminous compounds, and the gelatinous compounds (which are closely related to them, and are generally thought to be formed from them), compose the greater part of the animal textures, and are equally the groundwork of all animal structure, as starch is of vegetables, this inquiry involves the essential point of distinction, so far as chemistry goes, between vegetables and animals. It is well known that both LIEBIG and DUMAS have expressed a decided opinion that no albumen is formed in animals; and the latter author has contrasted, in a lively manner, vegetable and animal life in this respect, representing the former as always a reducing or deoxidating apparatus, and the latter as an apparatus of oxidation or combustion, *i. e.*, of the destruction, never of the formation, of any organic compound. But he does not appear to have adverted particularly to the question which seems to me the most essential in a physiological view, viz., what are the chemical changes during the state of life, whether

in vegetables or animals, which are distinctly at variance with the ordinary laws of chemistry, and which we must therefore ascribe to vital affinities?

It is evident that what, in physiological language, is commonly called Assimilation, includes two distinct actions, both, in many cases, as I believe, strictly vital; *first*, the mere selection and attraction of a part of a compound fluid, to be added to a living body; and, *secondly*, the *transformation* of the elements of two or more compounds, so as to form a new compound, similar to one already existing in the living body wherein this change occurs. If DUMAS's view of the subject were to be adopted, we should say that animals can exert only the first of these powers, the simple selection and attraction of one of the ingredients of a compound fluid by each organ or texture, without any power of *transformation*, or formation of new compounds; and accordingly, he says that "it is in plants that the true laboratory of organic chemistry resides."

But if we state the proposition thus generally, we may state various facts to shew, that it is incorrect. It is quite certain, as already stated, that oil or fat may be *formed* in animal bodies, by a new arrangement of the elements of starch, attended by an evolution of much of its oxygen, and of part of its carbon and hydrogen, effected by the aid of the oxygen of the air; and the influence (already noticed) of exercise, *i. e.*, of an increased application of oxygen, on this change, shews distinctly that the recent *ingesta* are liable to two influences in a living animal, one of which is an action of oxidation or combustion, throwing off water and carbonic acid, but the other is strictly an action of reduction, by which a quantity of oxygen is separated from its combinations in an organic compound, while a fresh compound, constituting part of the animal frame, is formed. And the fat of the animal body, which may be thus formed, is not to be considered as a merely unorganized appendage to the textures. It appears from some of LIEBIG's observations, that the muscular flesh of all animals, after being cleared of all visible fat, still retains a considerable and variable quantity in its substance; and we know that in two of the most important textures of the body, nervous matter and bone, fat is an essential ingredient.

In like manner, the formation of the essential ingredient Gelatin in the animal body is the result of a new arrangement of elements, attended with evolution of carbon and hydrogen, by the aid of the oxygen of the air, but probably not with absorption of oxygen.

In the case of Inflammation, we see distinctly that, in connection with an increased action of nutrition or deposition of plastic lymph, there is a transformation of portions of the blood to form the compound, very similar to gelatin, termed, by MULDER, the Tritoxide of Protein, which is found there in very unusual quantity; and in other morbid actions, in certain chronic malignant diseases, we see compounds, altogether foreign to the natural organization, formed and even rapidly extended; the formation of which is certainly neither a simply chemical act

of oxidation, nor a mere selection and appropriation of compounds previously formed in vegetables.

On the other hand, it is known that there is an evolution of carbonic acid as well as water from vegetables,—from the parts of fructification during their development even in the day time, and from all parts during the night; and it appears quite possible that, in both cases, this may be by a process of slow combustion, similar to the process of oxidation which DUMAS considers as characteristic of animal life only. For, although it has been stated by DUMAS that the carbonic acid given up by vegetables during the night is only what has been absorbed by their roots, and passed unchanged through their substance, yet I do not find any distinct proof of this in his writings. It is certainly true, that the organic compounds formed by vegetables, and taken into animal bodies, ultimately undergo in them a chemical change nearly equivalent to slow combustion, and are thus returned to the inorganic world; but this is in the processes of absorption, decomposition, and excretion, of the animal textures, to be considered presently; and this fact affords of itself no proof, that in the previous growth and development of animal textures, there may not be an actual formation of albuminous compounds, as well as of gelatin and fat.

These facts appear sufficient to shew, that there is no such direct opposition between vegetables and animals, as to the chemical results of their vital action, as DUMAS has represented; and even to make it probable, that, during the organic or vegetative life of animals, there will be a formation of albuminous matter, equally as of gelatin and fat.

In fact, this question can be only finally decided by experiments to shew whether or not the whole quantity of albumen deposited in the textures of a growing animal may be greater than that contained in its food; or whether the azote excreted, during a pretty long period, from an animal, by the bowels, kidneys, skin,\* and lungs† (for it appears to be well ascertained, that, from all these parts, there is a frequent, if not an habitual, excretion of azote), is greater, under any circumstances, than the quantity of that element contained in the albuminous portion of its food, which is the only ascertained channel of the introduction of azote into the animal system; and, although this is a difficult inquiry, we cannot suppose that the difficulties are insurmountable. If such an excess of excretion of azote shall be ascertained, it will be nearly enough to entitle us to conclude that albuminous matters can be formed in the animal body, and yield it during their decomposition there. It is not enough to say, that there is no occasion for more azote in the animal economy than is contained in the albuminous ingesta, because what is there contained is already in just the same proportion to

\* See GOLING BIRD on Urinary Deposits, p. 104.

† See DU LONG, quoted by DUMAS (Organic Nature, p. 106).

carbon and hydrogen, as that which exists in the blood, or in the textures of animals. As there is, in the whole of the ingesta of animals, a great excess of carbon and hydrogen over their proportion to azote in albumen, and as oxygen is always present in the blood, it is quite possible that a part of the azote of the albumen taken in, may be thrown off in combination with portions of those other elements, by the bowels and kidneys, without entering into the textures; and that the nourishment of the textures may be in part due to fresh albumen, formed in the animal body by help of oxygen from the lungs, and of azote taken in by another channel; just as we are nearly sure that part of the oil taken into an animal is often decomposed and thrown off, and that fresh fat is often formed from the starch or sugar of the ingesta.

There is one mode, pointed out by LIEBIG, in which we can have no doubt that azote must be introduced into the blood of animals, independently of the albuminous ingesta, viz., by the air which is contained in the water, and still more in the saliva, continually taken into the stomach. "During the mastication of the food, there is secreted into the mouth, from organs specially destined to this function, a fluid, the saliva, which possesses the remarkable property of inclosing air in the shape of froth, in a far higher degree than even soap-suds. This air, by means of the saliva, reaches the stomach with the food, and there its oxygen enters into combination, while its nitrogen is given out through the skin and lungs."\*

Now, what proof is there that the azote, thus believed to be set free in the stomach, is excreted, unchanged, by the skin and lungs? Is it not much more probable that it enters into fresh combinations in the *prima* *viae* and in the blood, and is only separated from the blood, when, by the agency of the oxygen of the air, acting, under the circumstances to be afterwards stated, with peculiar energy on some of the constituents of the blood, it is disjoined from its union with carbon and hydrogen.

In fact, the azote thus set at liberty in the stomach, must be in circumstances almost exactly similar to those in which, according to the statements of MULDER and others, ammonia is formed from air, even by the help of inorganic matter; still more when organic matter, although non-azotised, is present in a state of decomposition, or an analogous condition.† "By all porous substances ammonia is produced,—provided they are moist, are filled with atmospheric air, and are exposed to a certain temperature."

"When reddened litmus paper is hung up in a bottle, filled with pure atmospheric air, and when pure iron filings, moistened with pure water, are laid at the bottom, then the red litmus is quickly turned blue by the action of ammonia, formed from the nitrogen on the air, and the hydrogen of the decomposed water, the oxygen of which had combined with the iron.

\* LIEBIG's *Animal Chemistry*, pp. 113-4.

† MULDER, p. 149, *et seq.*

"Such a formation of ammonia continually takes place in the soil. There, atmospheric air is present, and consequently nitrogen; hydrogen is continually liberated, and thus the conditions necessary to the formation of ammonia are fulfilled as often as cellulose, ligneous matter, starch, &c., are changed either into humic acid, or into other constituents of the soil."

That a partial decomposition of organized matter takes place in the stomach, and is, indeed, the first part of the changes occurring during digestion, seems to be sufficiently proved by some curious and important observations of LIEBIG himself.\* "The fresh lining membrane of the stomach of a calf, digested with weak muriatic acid, gives to this fluid no power of dissolving boiled flesh or coagulated white of egg" (the supposed property of the Pepsin, or extract of the mucous membrane there.) "But if previously allowed to dry, or if left for a time in water, it then yields, to water acidulated with muriatic acid, a substance in minute quantity, the decomposition of which is already commenced, and is completed in the solution. If coagulated albumen be placed in this solution, the state of decomposition is communicated to it, first at the edges, which become translucent, pass into a mucilage, and finally dissolve. The same change gradually affects the whole mass, and, at last, it is entirely dissolved."

I think we cannot doubt, therefore, that the air introduced into the stomach of animals, and decomposed there, as LIEBIG supposes, must be in circumstances peculiarly well adapted for the generation of ammonia, or the setting free of its elements; which, as we have seen, is all that appears necessary to explain the gradual formation in the matters absorbed from the stomach, of albumen out of non-azotised ingesta; under the influence of vital affinities, similar to those by which albumen is formed in vegetables.

I am aware that LIEBIG states with confidence that experiments prove that the whole of the azote excreted in a given time by an animal, is not more than that which is taken in by its albuminous ingesta; but in this he relies chiefly on the experiments of BOUSSINGAULT, and these experiments are not considered by the author himself as altogether satisfactory; nor can they be satisfactory without farther investigation of the quantity excreted by the skin and lungs, into which he did not inquire. (See *Dumas*, p. 106.)

I admit it to be certain, however, from a simple comparison of the quantities of albuminous ingesta and the azotised excretions, that the formation of albumen in animals can be to no great extent; and I am clearly of opinion that the distinction drawn by LIEBIG, of the azotised and non-azotised ingesta of animals, and the evidence he has given of the chief destination and use of each, constitute the most important improvement lately made, in this department of physiology. It appears now ascertained; 1st, That the latter class of aliments are incapable, in

\* *Animal Chemistry*, pp. 110-1.

*themselves*, of adding to any of the animal textures except the fat ; but that they are the chief material on which the oxygen of the air acts to keep up the animal heat. 2d, That the main reliance of the animal body for the nourishment of all its parts must be on the former class of aliments ; their adequacy for that purpose being beautifully exemplified in the life of the chick *in ovo*, where all the textures are formed out of the albumen, partially converted into gelatin in the process, and with the addition of a small quantity of oil from the yolk ; the oxygen of the air being essential to the vital movement, but no farther concerned in the results, than as it carries off a certain portion of the carbon and hydrogen from the moving matter, and so occasions a loss of substance during the process of incubation. 3d, That the azotised ingesta, or the textures formed from them, are themselves liable to this action of the oxygen when the non-azotised ingesta are deficient ; and, therefore, that an important use of the non-azotised food is, to protect the albuminous constituents of the blood and the animal textures, from an influence of the oxygen of the air, which, but for that protection, would be injurious, and ultimately destructive. And I may perhaps be allowed to state what seem to me the most important results, both as to Physiology and Pathology, which are involved in these principles.

1. Our ideas of the use of the digestive apparatus of animals are rendered much more simple and precise. I have stated, indeed, that DUMAS appears to have erred in the way of extreme simplification, when he says that "an animal only assimilates" (*i. e.* selects and attracts) "organic structures already formed ; that he forms none ;" that "digestion is therefore a simple process of absorption, soluble substances passing directly into the blood (*i. e.* by the veins), for the most part without alteration, and insoluble substances making their way into the chyle after having been sufficiently comminuted, to be imbibed by the lacteals." But although we suppose that certain transformations, as well as simple absorption, must be commenced, at least, in the digestive organs, we are sure that no complication of apparatus is necessary for accomplishing them ; the most important of all transformations necessary to life taking place in vegetables, and in organs of extreme simplicity.

The following may be stated as the purposes which are served by the digestive apparatus of every kind of animal, whether carnivorous or herbivorous, and the greater complexity of the arrangements in the latter tribes must be considered as intended merely to present a larger surface, and afford a longer time, for the accomplishment of changes which are, in fact, identical in kind, and all of which may be effected in the simplest form of apparatus.

(1.) This apparatus is obviously necessary, as stated by CUVIER, for the support of textures whose vital action is dependent on a continuous supply of nourishment, to afford that continuous supply from aliments, the reception of which, in the case of animals, is only occasional, and sometimes long delayed.

(2.) It is useful, as providing for the separation and immediate expulsion

from the body of those parts of the ingesta which are wholly inapplicable to nutrition, and for which no part of the living structure has any vital attraction.

(3.) It is especially useful, as giving the necessary fluidity to aliments which must be moved to all parts of the animal frame, and applied to the nourishment of the organs in a state of minute subdivision, but which are often introduced into the system in a solid form, having been formed in one living structure, vegetable or animal, and applied to the purpose of nutrition in another, and often after a long interval of time. For this purpose, it appears certain, that various contrivances are employed: in many cases, the mechanical process of attrition is an essential preliminary; in all cases, water is employed; in most cases, it would appear, especially from the observations of LIEBIG, that a certain degree of incipient decomposition—speedily arrested by the action of vital affinities, but beginning on the mucous membrane, and extending to the mass of aliments—precedes and aids the action of the solvent; just in like manner as an incipient decomposition of starch, and formation of soluble sugar, precedes the development of vegetable shoots and flowers; but especially the requisite fluidity is given by solvents, applied at different spots, and which are prepared from the blood, under the influence of appropriate stimuli, by a vital attraction, or selecting power, existing at those parts. Thus, an acid liquor is prepared at the stomach and at the cæcum, and, with a similar intention, according to recent observations, it would appear, that an alkaline liquor is prepared in the salivary glands, liver, and pancreas.

(4.) The most soluble part of the ingesta, and especially the amylaceous portion, must necessarily be taken up by the veins, and carried directly to the liver to form bile; and as this portion, unless combined with azotised matter, is inapplicable to the nutrition of any texture except the fat, we see here one ground for the opinion to be afterwards stated, that the animal matter of the bile is chiefly useful as a part of the provision for the agency of oxygen, and the maintenance of animal heat.

(5.) Although we are uncertain how far transformations of the organic compounds are effected in the animal economy, as preliminary to nutrition, yet we have seen that some such transformations must be admitted as a part of the living power of animals, for the formation of fat, of gelatin, perhaps also of albumen; and this process is pretty certainly commenced in the chyme, in the primæ viæ, and particularly in the organized globules there formed, to be afterwards carried on in the course of the circulation.

2. In the next place, the principles laid down by LIEBIG as to the distinction between the azotised and non-azotised classes of aliments, enable us distinctly to understand the law of PROUT, as to the necessity of a mixture of at least two of the three kinds of aliment which he distinguished, the albuminous, oily, and saccharine, in order to maintain life. In fact, I have no doubt we may go farther (in

consequence of the discoveries made as to the existence of albuminous matter in vegetables since Dr PROUT wrote), and assert that more or less of albuminous matter is always necessary, because it alone, of all the solid or fluid ingesta, contains the azote which is a necessary constituent of animal textures; and that it must be combined either with starch or with oil, or both; partly because oil is an essential constituent of parts of the body, and must either be furnished ready made, or formed in the body from starch; and partly because the animal heat, the first requisite of vitality, can only be maintained by the oxygen of the air combining with carbon and hydrogen in the blood; and if it does not find these elements in sufficient quantity, and in a fit state for such union, in the other constituents of the blood or of the textures, it will attack the albuminous portions of the blood and textures, and so cause decomposition and wasting of the body.

We see likewise the importance of oily food, which, containing the largest proportion of carbon and hydrogen, will yield to the oxygen the largest quantity of carbonic acid and water, and therefore evolve the greatest quantity of caloric,—in cold climates; and of saccharine and amylaceous food which, containing more oxygen in itself, will furnish a smaller quantity of calorific compound with the oxygen of the air,—in warm climates; particularly as the supply of heat from this kind of ingesta is farther regulated and moderated by the action of the liver, in a way to be afterwards considered.

3. We understand the principle, on which the wasting of the body is effected, either in cases of denial of aliments, or of disease preventing their reception or digestion; *i. e.*, we understand that the oxygen of the air, introduced regularly and uniformly in the blood by respiration, but meeting there with very different compounds as the privation of ingesta continues, is the main agent in the process; acting first, as it must do in the healthy state, on the non-azotised compounds existing in the blood, oil, cholesterine, or other constituents of the bile, and starch, or matters recently formed from starch, and nearly destitute of azote, and which readily give up their carbon and hydrogen; next acting on the non-azotised portion of the solid textures, *i. e.*, the fat, and causing emaciation; afterwards acting on the albuminous portions of the blood itself, rendering it more serous; and then acting directly or indirectly on the solid textures, determining ultimately such absorption of the substance of the brain and nerves as causes delirium and insensibility, and such absorption of the muscular textures, as causes death by asthenia. It can only be by successively acting on these different matters, that the oxygen can find the quantity of carbon and hydrogen with which it must unite in the course of the circulation, to account for its own disappearance and for the quantity of carbonic acid which is known to be still thrown off, for days and weeks, while no carbonaceous matter is added to the blood; and the order in which the successive changes on the sensible qualities and functions of the body occur, corresponds perfectly with the belief that the oxygen, acting on the dif-

ferent parts more or less rapidly, as they give up their carbon more or less easily, is the immediate agent by which the extenuation of all is effected.

4. We understand, certainly not completely, but better now than formerly, the nature of the changes which take place in animals long fed on one kind, even of albuminous food, equally as when albumen is withheld; and which appear in both cases to indicate a deficiency of the albuminous constituents of the blood; and likewise, certain phenomena in disease, connected with deficiency of those albuminous constituents.

There are several facts connected with such diseases which we cannot understand, until we have some farther information as to the relation to each other in the living body, of the different constituents of the blood which are albuminous,—the red globules which contain the largest portion of that matter,—the white globules which seem to be more immediately concerned in nutrition,—the albumen of the serum,—and the fibrin, which is in the smallest quantity, and which differs from the albumen only in the peculiar (vital) attraction or aggregation among its particles; and which appears to exist in the living state partly, and, according to ANDRAL's observations, entirely, in the white globules above noticed. Until the relations of these different matters are better understood, we cannot explain how some of the most striking symptoms of that disease which seems to be the most directly produced by inadequate nourishment, viz., the Scurvy, are produced. But in that disease we now know that there usually is a great deficiency in the quantity of red globules, as well as either in the quantity or in the vital power of the fibrin; and we can now distinctly understand how it should happen that scurvy should shew itself, both when there is a long-continued deficiency of sufficient albuminous nourishment, and likewise when the nourishment taken is too exclusively albuminous;—most frequently, in this last case, when it is at the same time salted and hardened, and difficult of solution in the gastric juice, but, likewise, as repeated experience has shewn, when it is fresh and nutritious, but uniform.\* In the first case (exemplified in several prisons of late years), there is a simple deficiency of azotised nourishment; in the other, there is a deficiency of the non-azotised matter which should protect this nourishment; the oxygen of the air therefore acts upon it, and the chief result seems to be, that the formation of the globules, apparently both of red and white globules, is prevented. Both cases are illustrated by what happens in BRIGHT's disease of the kidneys, where there is such a change in the vital action of these organs, that they throw off prematurely much of the albumen of the blood; the effect of which on the constitution of the blood is to diminish greatly all its azotised constituents, even although a full quantity of azotised food is taken; the specific gravity of the serum falling, and the proportion of the red globules to the other constituents of the blood becoming

\* See BUDD on Scurvy, in the Library of Medicine.

as small as in the worst diseases of the stomach ; while at the same time there is a tendency to extravasation, not indeed of the red globules as in scurvy or purpura, but of the serous part of the blood,—equally dependent as the extravasations in scurvy, on the condition of the blood itself.

But not only do we understand that there should be this great deficiency of the albuminous contents of the blood in scurvy, resulting after a time from the use of exclusively albuminous food, equally as from the denial of such food, or the continued morbid discharge of albumen from the blood, or the deficiency of digestive or assimilating power, as in chlorosis ; but we understand, likewise, what appears at first sight paradoxical,—how the evils resulting from this state of the blood should be remedied by the use of food which is not albuminous, by succulent vegetables and vegetable acids. I do not say that we can understand exactly the efficacy of the small quantities of the vegetable acids in particular, which appear to be effectual in relieving the symptoms of scurvy ; but we can distinctly perceive the principle, that, when a quantity of non-azotised matter is taken into the blood, the oxygen of the air will have less power to act injuriously on the albuminous constituents of the blood.

But although the distinction of the azotised and non-azotised ingesta, and the view taken of the chief offices of the two, enable us to understand much that was formerly obscure in regard to these points, yet it is not necessary, in acquiescing in this doctrine, to deny the possibility of the formation of albumen in the animal body. We may state other facts, occurring both in health and in disease, which are hardly consistent with the belief, either that no albuminous matter can be formed there, or that none of the albuminous matter taken into the body is applied immediately to the formation of excretions.

1. When we attend to the invigorating effect of pure air and of exercise on all vital action, and to the evidence we have of the increase of the red globules of the blood (the chief part of its albuminous constituents), and of the muscular texture throughout the body under their influence, it seems hardly possible to doubt, that the effect of the increased introduction of oxygen into the system is a real increase of the deposition of albuminous matter. Now, if there be no formation of albumen in the animal body, the increased introduction of oxygen is the increased application of a cause only of degradation or destruction of such matter ; whereas, if albumen can be formed out of the non-azotised ingesta, as we have seen that there must be a considerable discharge of carbon and hydrogen, by help of the oxygen of the air, before the remaining elements can fall into the arrangement necessary for that purpose, we at once perceive that the effect of pure air and of muscular exertion must be, to increase the formation of that albuminous matter in the blood.

The effect of exercise in preventing or relieving the symptoms of Scurvy, ap-

pears to me peculiarly important in this inquiry. If we suppose that the immediate cause of the diminution of the albuminous matter in the blood, which takes place in that disease, is the action which the oxygen exerts on that matter,—in consequence usually of the small proportion of non-azotised matter which it finds in the blood,—and if the animal system has no power of forming albumen, we do not see how the increased introduction of oxygen should have any but an injurious effect; but if by means of it a part, even a small part, of the blood, consisting of amylaceous and oily matter, can be made to yield albumen, at the same time that it gives out carbonic acid and water, we can distinctly understand how the accession of scurvy should be retarded or prevented. And, in fact, we find that this effect is very generally observed, as the result of habitual and invigorating exercise.

It is stated by Sir E. PARRY, that in Greenland the scurvy seldom makes its appearance among the natives until they confine themselves in their close huts for the winter, although the diet which they use when thus confined is the same as when they are moving about.

In our own country we have had various examples, on a large scale, of scurvy affecting prisoners long confined, although the diet on which they lived would not appear to have been materially different from that on which many of the lower ranks, particularly in Scotland, when at large, preserve their health, and are fit for much muscular exertion. Thus the diet of the prisoners at the Millbank Penitentiary in 1822, on which more than half of them became scorbutic (indeed three-fourths of those above three years confined), consisted of  $1\frac{1}{2}$  lb. of brown bread daily, with one quart of soup, which soup had been made with from 2 to 3 oz. of the meat of ox-heads, with 3 oz. of garden stuffs, and was farther thickened with peas or barley; and at Coldbathfield Prison, about the same time, scurvy appeared pretty extensively within a few weeks after the diet had been reduced to  $1\frac{1}{2}$  lb. of white bread, with 1 pint either of soup or gruel in the day, and  $\frac{1}{2}$  lb. of beef on Sunday.\* Comparing this diet with that of many labouring men in Scotland, consuming about  $1\frac{1}{2}$  lb. of oatmeal, and *perhaps* 1 pint of milk daily, we can hardly doubt that the air and exercise of the latter exert an influence to improve the condition of the blood; whereas, upon the supposition that the oxygen of the air can give no help in forming albumen, that influence, in so far as the production of scurvy is concerned, should be only injurious.

2. All the phenomena of Scrofulous disease appear clearly to indicate that what we call the scrofulous diathesis, is necessarily connected with a deficiency in the nutritious or albuminous constituents of the blood; and we can now put that proposition in a definite and tangible form, in consequence of the important observation of ANDRAL,—that in numerous trials made on the blood of persons

\* See HOLFORD's Second Vindication, &c. &c., pp. 4, 5, 10.

affected with tubercular disease, even in its earliest stage, he had always found the proportion of the red globules, in which the largest part of the albuminous matter is contained, less than the lowest proportion which he had ever found in healthy persons (less than 100 in the 1000 parts, the average proportion being 127). Now there is no proposition, in regard to the external causes of the scrofulous diathesis, which has been more anxiously investigated of late years, or, on the whole, more fully established than this, that it is, *cæteris paribus*, increased by atmospheric impurity and by sedentary habits, and diminished by pure air and exercise. Yet, if the animal frame cannot form albuminous matter, the only effect on the albuminous portion of the blood, of the increased introduction of oxygen which is implied in these circumstances, must be, to hasten the decomposition and expulsion of the albuminous matter absorbed from the *primæ viæ*. I do not state this fact, as affording more than a presumption against that opinion, because I am aware it may be said that, under the influence of fresh air and exercise, a larger quantity of albumen is taken into, or is absorbed from, the stomach and bowels, than in sedentary persons breathing impure air; but in so far as we can judge from the quantities taken into the body, I am pretty certain that the experience of medical men goes to prove that, when the quantities and kind of *ingesta* are *the same*, the beneficial effects of air and exercise in counteracting the scrofulous tendency,—*i. e.*, as I believe, in increasing the proportion of albuminous matter in the blood, may be distinctly perceived.

Indeed, independently of disease, I am strongly inclined to believe, that the nourishment of the animal body, and especially of the muscular textures, by a given quantity of *ingesta*, may be distinctly observed to be promoted by exercise, which is hardly conceivable on the supposition, that the only truly chemical changes which take place in the body are of the nature of oxidation, or slow combustion, and consequent excretion, in which the oxygen of the air is the chief agent.

3. The phenomena of Diabetes seem to me very adverse to the idea of the amyloseous matter taken into the system, being wholly inapplicable to the formation of albumen. In that disease, the digestion and appropriation of albuminous matter appear to go on even with unusual rapidity; and the urea which is contained in the urine, often in increased quantity in the early stage, and which is always easily obtained from it in full quantity immediately before death, shews that this matter is ultimately disposed of in the usual way in the animal economy; the amyloseous matter taken in must be the source of all the sugar which is formed in so great quantity, and which characterizes the disease; and it seems to be liable only to that kind of decomposition to which such matter is liable, by simply chemical affinities, at that temperature, and under the influence of water and oxygen; it is converted into sugar, and runs off by the kidneys, *i. e.*, it seems to be actuated by no vital affinity. Now, if all the starch taken into the

living body were useful, as this theory supposes, only by yielding to the simply chemical action of oxygen, and so giving off caloric, we do not see how these changes in diabetes should interfere with that office, or how they should involve so great derangement of the system, and particularly so much gradual wasting of all the textures. But if the starch taken into the system is liable to transformations resulting from vital affinities, and in which albumen is generated, then we can understand, that a disease in which starch seems to lose all tendency to vital action, and is rapidly thrown off, should be attended with this emaciation and debility.

4. When we attend to the phenomena of Lithiasis, *i. e.*, the morbid formation of uric acid, and the effects of different kinds of diet upon it, we meet with facts hardly to be reconciled to the idea of the albuminous ingesta being all destined for nutrition, and the non-azotised for combination with oxygen and excretion. It is well known, that LIEBIG pointed out that this diseased state depends on imperfect oxidation of the albuminous matter in the blood, which is destined to excretion (causing a formation of uric acid, when a fuller oxidation would produce urea and carbonic acid); and that he supposed all the albuminous matter which unites with oxygen in the blood, to be the product of absorption from the textures, the recently introduced albumen being, according to his theory, destined for nutrition only. Hence he argued, that a vegetable diet, increasing the quantity of non-azotised ingredients of the blood, with which the oxygen most readily unites, would leave less oxygen for the azotised or albuminous constituents, and aggravate the disease. But experience has shewn, particularly since the observations of MAGENDIE were published, that the disease is more generally mitigated by a vegetable diet, under which, as it would appear, the whole quantity of azotised matter in the blood and in the urine is diminished, and the oxygen taken in is sufficient for its full oxidation. And the experiments of several authors have shewn, that the quantity of azotised matter thrown off by the kidneys increases greatly (may be nearly doubled) within a few hours after highly azotised food is taken. From which facts it would appear, that the azotised matter thrown off by the kidneys, is derived not merely from absorption of the textures, but likewise directly from the ingesta; and if so, the distinction of the azotised ingesta, destined only for nutrition, and the non-azotised, destined only for excretion, is not observed by nature; and it becomes extremely probable, that, as part of the albuminous ingesta are excreted, so a portion of fresh albuminous matter is formed in the blood, and applied, in the first instance, to the nutrition of textures.

IV. It is at all events certain, that Gelatin is formed in the living body, and its composition, as stated by LIEBIG,  $C_{108} N_{18} H_{84} O_{40}$   
or by MULDER,  $C_{117} N_{18} H_{90} O_{45}$   
compared with that of albumen,  $C_{144} N_{18} H_{108} O_{42}$

seems evidently to denote that it is most probably formed from the elements of albumen, by a farther separation of carbon and hydrogen, aided by the agency of the oxygen of the air. LIEBIG seems to consider it as certain, that this separation must be from the elements of albumen, and, therefore, that gelatin can only be formed from albumen ; but it is possible, also, that it may take place from the elements of starch with ammonia, oil being formed at the same time.

If we take the numbers given by MULDER as representing the composition of gelatin, this appears very distinctly. Thus,

	C	N	H	O
To starch,	120	...	100	100
Add ammonia,	...	6	18	...
	120	6	118	100
From this subtract,				
Elements of gelatin,	39	6	30	15
	81	...	88	85
And again, 5 equivalents of fat, 60	...	50	5	
	21	...	38	80

which is exactly 21 equivalents of carbonic acid with 38 of water, excreted by the skin and lungs.

The "tritoxide of protein," lately so fully considered by MULDER, approaches so nearly in its properties to gelatin, that we may presume its formation will depend on nearly the same conditions; and accordingly we find, that it may be formed from albumen by the long-continued application of heat, air, and water ; and that it is formed in large quantities in inflamed parts, where the stagnation of arterial blood (carrying oxygen) and the increased temperature plainly indicate that an increased application of oxygen is going on.

But as there is a remarkable discrepancy of statement as to the chemical relation of gelatin to the albuminous compounds, we must regard the precise nature of the change effected in this department of the animal economy as somewhat doubtful.

In thus attempting to trace the nature of the processes, wherever they may be carried on, by which carbon, nitrogen, hydrogen, and oxygen, uniting with other elements in smaller proportion, fall into the combinations which constitute the animal textures, and in attempting likewise to assign the province of the vital affinities in these processes, we must admit very material deficiency of information. We do not perceive, for example, how it should happen that the amylaceous matter, which forms the greater part of the ingesta of so many animals.

should hardly appear in their blood, even in that diseased state (diabetes) in which it passes off so copiously, in the form of sugar, by the kidneys. Neither is it easy to understand why the gelatin, formed probably in the course of the circulation, and deposited in so large quantities from the bloodvessels, should not appear in the blood. We are very imperfectly informed as to the origin, the use, or even the composition, of that animal matter, or rather congeries of animal matters, to which the name Extractive is applied. We are still in doubt as to the purposes served by the globules of the blood, both red and white, and the place and mode of their composition and decomposition.

But, admitting all these difficulties as to the details of the chemical changes, still these leading facts are ascertained:—that, in the cells of living vegetables, amylaceous, fatty, and albuminous compounds are formed,—and that, in the circulation through different parts of animal bodies, these compounds are selected and appropriated, and, in some instances, farther transformed, so that a farther formation of oily matter, and a new formation of gelatin, and probably of albuminous matter, takes place, applicable to the immediate nourishment of textures; that all these materials are formed ultimately from carbonic acid, water, and ammonia, existing in the atmosphere; that the carbon, originally fixed from the carbonic acid, is the most essential of all the ingredients, and the proportion of oxygen in all these organic matters, much less than in the inorganic compounds from which they are derived: that the affinities whereby the carbon is enabled to enter into these combinations with the other elements, existing in these organic compounds, to the exclusion of much oxygen, are peculiar to the state of life, and liable to variations by causes which do not affect dead matter; and that, in so far as the oxygen of the air is concerned in the formation of any of these compounds, it acts only by carrying off such portions of carbon and hydrogen, as enable the remainder of those elements to fall into certain new combinations with the others which are there present.

We may state another difficulty here, as leading directly to the next important question in vital chemistry, the rationale of the Excretions; viz., Why does the oxygen, which certainly attaches itself to the red globules in the lungs, not give evidence of its combining with the carbon in them, by giving them the dark colour, until it has passed along the arteries, and through the capillaries of the system, and entered the veins? This fact is noticed both by PROUT and LIEBIG. "The oxygen absorbed at the lungs," says Dr PROUT, "remains in some peculiar state of union with the blood (*query*, As oxygenated water, or some analogous compound?) till the blood reaches the ultimate terminations of the arteries. In these minute tubes *the oxygen changes its mode of action*; it combines with a portion of carbon, and is converted into carbonic acid."—(*Bridgewater Treatise*, p. 536.)

LIEBIG goes a step farther in explanation of the change of mode of action of the oxygen, when he says, "The globules of the blood serve to transport the oxy-

gen, which they give up in their passage through the capillary vessels. Here the current of oxygen *meets with the compounds produced by the transformation of the tissues*, and combines with their carbon to form carbonic acid, and with their hydrogen to form water."—(*Animal Chemistry*, p. 60.) But neither author has stated as clearly as I think may be done, on what principle it is that the oxygen changes its mode of action when it meets with these products of the transformation of the tissues ; or, in simpler language, with the matters that have been absorbed from the living tissues. I believe the true reason to be, that this is an exemplification of a general principle of essential importance, which has been partially stated, but never, so far as I know, fully developed, viz., that *all vital affinities are of transient duration only* ; and that those which actuate the matter of animal bodies especially, soon fail of efficacy, and at the temperature, and under the other conditions there present, give place to simply chemical affinities, which determine the formation of a very different set of compounds ; therefore, that as long as the oxygen is passing along the arteries, and is in contact with albuminous matter, to which vital properties have been recently communicated, and which are actuated by vital affinities, it has little power to affect them ; but when it meets with the same compounds in the substance of the textures, or already absorbed from them, *i. e.*, with albuminous or other animal matter, which, according to the expression often, but vaguely, used, has become *effete*, or has lost its vital properties, it can act on them in the living body in like manner as it does, at the same temperature, in the dead body.

But, in order to establish this point, it is necessary to enter on the second part of our inquiry into the chemical changes of animal bodies, *i. e.*, the peculiarities of the Excretions ; *first*, of the greatest and most general of all the excretions from living bodies, the carbonic acid thrown off from the respiratory organs, both of animals and plants, of which Dr PROUT says, that " the precise use of its constant evolution we know not,"—and *then*, of the other excretions from animal bodies. Until we have precise knowledge of the purpose which is served, and of the laws which are obeyed, by the matters which are continually expelled from living bodies, it is obvious that our notions in regard to vital affinities must be very unsatisfactory. In entering on this subject, I assume it as ascertained that all the matters, peculiar to the excretions from the living body, pre-exist in the blood, and are only eliminated from the blood at the organs where they appear ; so that any chemical changes necessary for their formation, take place either in the cells of the textures, or in the circulating blood, or both, not in the glands which separate them, at least not externally to the vessels of those glands.

The first idea that must occur to every one who considers that large quantities of extraneous matter enter into every living body, different from those that can be traced in any of its textures, is, that the excretions from living bodies are simply those portions of the *ingesta* which are not applied to the maintenance of the or-

ganized structure. And that certain excretions are strictly of this character, seems to be fully ascertained, *e. g.*, the great excretion of oxygen from living vegetables, is merely separated from the carbon of the carbonic acid which enters them, when that carbon unites with the elements of water to form starch; and a part, at least, of the carbonic acid and of the water which are thrown off from a living animal, when it lives on sugar or starch, and forms oil or fat, or when it lives on albuminous compounds and forms gelatin, appears, from what was formerly stated, to be formed, by help of the oxygen of the air, from such portions of the carbon and hydrogen, of the starch or of the albumen, as are excluded when the new arrangement takes place, by which fat and gelatin are formed.

It is important to keep in mind, that, in regard to *all* the excretions, we have sufficient evidence of their being *partly* furnished in this way; *i. e.*, consisting of elements which have been taken into the body, but which are either redundant, or inapplicable to the nutrition of its textures; and that these are thrown off either alone, or combined only with a portion of the oxygen absorbed from the air, and the influence of which on the excretions will be considered afterwards. Thus it is certain, that part of the excretion from the bowels consists merely of unassimilated ingesta. It has been lately stated, with much probability, that certain matters in a putrescent state, absorbed into the circulation, find a natural vent in the mucous glands of the lower intestines.\* When we consider that the bile is secreted chiefly from the venous blood of the *vena portæ*, and that this must necessarily be usually loaded with matters recently absorbed by the gastric and mesenteric veins, and not yet taken into the general circulation; and when we farther remember the small proportion of azote in the animal matter of bile, and the large quantity of this secretion in herbivorous animals, we can have no doubt that much of the matter (particularly the non-azotised matter) taken up by the veins, is brought to the liver only that it may be discharged thence in the form of choleic acid. We know likewise, that certain volatile matters, as alcohol or turpentine, however taken into the system, are excreted by the lungs, either unchanged or united (as in the case of phosphorus), with a certain portion of oxygen. And, in like manner, we have evidence, already stated, in regard to the secretion at the kidneys (although that evidence was not duly considered by LIEBIG), that a considerable part of it is frequently formed from matters recently absorbed into the blood from the *primæ viæ*, and which had never been applied to the nutrition of textures. As we know that the quantity of uric acid and urea, the most highly azotised of the animal compounds excreted, is much greater under the use of animal (*i. e.*, highly azotised food) than of vegetable, while the health and even the muscular strength

\* See CARPENTER'S Physiology, 3d edition, p. 685. This principle is probably of great importance in the pathology, both of hectic and typhoid fever, and of that form of dysentery which seems to result, as a specific inflammation, from certain putrescent miasmata.

may be equal; and that by the use of highly azotised animal food, the animal matter of the urine may be increased, according to CHOSSAT's observations, from 9.9 grains in the ounce to 17; and the proportion of urea voided may be even increased from 237 to 819; and, as we learn from the experiments of CHOSSAT, that a great part of this increase may take place within a few hours after animal food, rich in azote, is taken, we can have little doubt that a considerable part of that azotized food must have passed off by the kidneys without having been applied to the nutrition of any of the textures. And this appears to be confirmed by observations on that disease which arises from a morbid formation of uric acid in the system, because I think two facts may be regarded as nearly ascertained in regard to that state, viz., 1. That it depends essentially on imperfect oxidation of the azotised matters contained in the blood, and destined to excretion;\* and, 2. That it is most generally and effectually diminished by a vegetable diet, lessening the quantity of azotised matter taken into the body; whereas, if all the azotised matter destined to excretion had been the production of absorption in the body itself, the introduction of much non-azotised matter, with which the oxygen of the air certainly combines in the circulation, would have left less oxygen to unite with that effete azotised matter, and would have determined, therefore, a greater production of the imperfectly oxidised uric acid, as proportioned to the urea.†

These facts seem sufficiently to illustrate and justify the common opinion, that the excretions are furnished, in part, by such portions of the ingesta as are either inapplicable to nutrition or redundant; and which are, therefore, either

\* This is shewn thus—

	C	N	H	O
Uric acid	100	40	40	60
Add water	...	...	40	40
„ oxygen,	...	...	...	60
	100	40	80	160
Subtract urea,	40	40	80	40
	60	...	...	120 = 60 CO <sub>2</sub> Carbonic acid.

† LIEBIG, taking for granted that it is the non-azotised portion of the ingesta only, that is united with oxygen from the air in the course of the circulation, thought the use of vegetable food improper in this state of the body, as absorbing the oxygen, and causing, therefore, imperfect oxidation of the azotised matter absorbed from the textures, and about to form urea and uric acid. But the observations of MAGENDIE and others, shewing that both in health and disease the proportion of uric acid formed is generally less under a vegetable diet than an animal, particularly when taken in connection with the facts stated above as to urea, must be regarded as proving, that the idea of non-azotised food having that exclusive tendency to unite immediately with oxygen in the blood, must be erroneous.—See Carpenter's *Physiology*, § 849, 850.

excluded from the new combinations which are formed in a living body, or rejected from the selections which are there made.

Now, if we consider it as ascertained, that a part of all the aliments taken into a living animal body, combines immediately with the oxygen of the air, in the blood, and is thrown off by the excretions in the form of water, carbonic acid, and ammonia,—or in forms which tend towards, and quickly resolve themselves into, these compounds,—we see a distinct confirmation of what was formerly stated, as to the nature of vital affinity, viz., that it does not, properly speaking, supersede ordinary chemical affinities, but is merely superadded to them; so that chemical compounds, taken into animal bodies, are subjected to these attractions as well as others, and are divided between the substances thus acting upon them, in proportions varying probably, as in other cases, according to the strength of the affinities and the quantities of matter exerting them. This, indeed, appears sufficiently demonstrated by the effect of exercise (already considered) on the excretions by the skin and lungs, on the one hand, and on the deposition of fat or of albuminous compounds, on the other; we know, that, as the quantity of carbonic acid and water thrown off are increased by that cause, the quantity of fat deposited from the blood is diminished,—implying that, by the increased quantity of oxygen presented to them by the blood, portions of the carbon and hydrogen of the ingesta, which would otherwise have been subjected to the vital affinity which forms fat, have yielded to the simply chemical affinity which disposes them to unite with oxygen and pass off; and again, it is at least highly probable, that, under this increased supply of oxygen, increasing, by a simply chemical attraction, the proportion of carbon and hydrogen which escape from the ingesta, the effect of the vital affinity by which the remaining elements of the ingesta combine to form albuminous matter, is likewise increased.

But we have next to consider the evidence for the existence, and the object and importance of another and totally distinct source, long believed to contribute to the formation of the excretions, viz., matter which has formed part of the textures of the living body, and been re-absorbed from them, with the intention of being thrown out of the body; *i. e.*, the dependence of excretion on what Dr PROUT calls “destructive assimilation.”

The mixture of this matter with the blood appears to be necessary for all the changes there, from which the different excreted fluids result; or, it may be supposed not merely to escape itself, but to act as a ferment, promoting these changes, and thereby determining the entrance into these combinations, and the expulsion from the body, of the portions of the ingesta which are not required for nutrition.

The term *effete* matter has been very generally employed in discussions on this subject; but it does not appear to me, that any very definite idea has been annexed to the term, nor that any principle has been pointed out to explain how

animal matter becomes effete,—why the absorption of matter once deposited in the textures should be a necessary concomitant of animal life,—or why the elements composing these textures should enter into new combinations, and then should require to be expelled from the body. But I am persuaded it will appear, on examining the subject, that the principle formerly stated, of the *transient existence of vital affinities* in every portion of matter which becomes endowed with them, is both supported by sufficient evidence, and adequate to the explanation of these phenomena.

The leading facts on which this conclusion may be rested are the following:—

1. We know that a continual process of absorption and change of materials is always going on in every living animal texture, and is, in fact, the cause why a continual act of nutrition (the most characteristic of all the functions of animals) is essential, not only during growth, but even in the decline of the body, to the maintenance of its structure and properties.

2. We know that, simultaneous with this absorption, there is a continual process of excretion going on from every living animal, and that, by these excretions, a quantity of all the elements constituting the animal textures is continually thrown off; and farther, it appears to be indicated, although I cannot say fully established by LIEBIG, that the sum of the chemical elements thrown off by the different excretions sufficiently accounts for (the presence of oxygen and water being kept in mind), not merely the *part* of the blood which is not applied to the nourishment of the textures, but the whole of the blood.\*

3. We know that the excretions, at least that some of them, not only continue but increase, particularly under any increased muscular exertion, and that their nature remains the same, in an animal deprived of aliment, and in a state of rapid emaciation, as in one that is fully supplied with aliment, and perfectly nourished. “In a starving man, who is in any way compelled to undergo severe and continued exertion,” says LIEBIG, “more urea is excreted than in the most highly fed individual, if at rest. In fevers, and during rapid emaciation, according to PROUT, the urine contains more urea than in health.”†

While these facts prove uncontestedly that a great part of the matter thrown off from every living body must be the product of absorption from the body itself, let us next consider the information that we have, as to the change which is wrought upon the absorbed materials before they are expelled from the body.

1. The most leading fact in this part of the subject is, that, in the natural state, *none of the organic compounds which exist in the textures, appear in any of the*

\* See Animal Chemistry, p. 136 and 152. This conclusion, however, is not to be regarded as established, various fallacies being connected with it. In fact, it seems to me only certain that the carbon and nitrogen are in the same proportions in the excretions as in the blood.

† Animal Chemistry, p. 139.

*excretions*, although it can only be through the excretions that they disappear from the body, and although the earthy or saline matters absorbed from the textures are there found. The animal compounds existing in the textures must therefore have undergone a great chemical change, in the process by which they are removed from their place in the living body, and finally expelled from it; and this notwithstanding that they are placed in circumstances exactly similar to those, in which their previous original separation and deposition from the blood in the minute capillaries took place.

2. The substances into which these animal compounds (with or without additions derived directly from the *primæ viæ*) have resolved themselves almost entirely before they are thrown off in the excretions, must be, the water which is the basis of all, the carbonic acid thrown off by the lungs and skin, the choleic acid thrown off by the liver, and the urea and uric acid thrown off by the kidneys. All these last we know to be formed in the course of the circulation, not in the organs by which they are separated from the blood; and all possess these essential peculiarities, distinguishing them from the compounds forming the textures; *first*, that they are crystallizable, *i. e.*, the elements composing them are so arranged as to be capable of assuming the definite forms peculiar to inorganic matter; and *secondly*, that they are poisonous to the living body when they are allowed to accumulate in the blood, and, therefore, that their continual expulsion is essential to life.

3. When we farther examine these compounds, into which the animal textures have resolved themselves before they are expelled from the body, we find that they are substantially the same as those, into which these textures are ultimately converted after death, by help of union with oxygen, when in contact with air and water, and at a certain temperature,—viz., water, carbonic acid, and ammonia, the small quantities of sulphur and phosphorus contained in the animal textures, combining likewise with oxygen so as to form sulphuric and phosphoric acids before they are expelled.

	C	N	H	O	
Thus Urea consists of	100	100	200	100	
Add water,	...	...	100	100	
	100	100	300	200	=Carbonic acid and ammonia.
Again, choleic acid consists of	76	2	60	2	
Subtract urea	2	2	4	2	
	74	...	56	20	Adding oxygen freely,
	...	...	...	184	
We have, acid and water.	74	...	56	204	$= 74 \text{ CO}_2 + 56 \text{ HO}$ carbonic

Thus the general fact seems established, that the excretions from the living body are only an intermediate stage between the organic compounds, forming the animal textures, and the inorganic chemical compounds into which these are ultimately resolved after death; and that in the same living body, and in the same parts of it, at the same temperature, and when in contact with the same substances, the same chemical elements, carbon, nitrogen, hydrogen, and oxygen, are continually acting on one another so as to form two distinct sets of compounds; the one set peculiar to living bodies, always attaching to them certain saline and earthy matters, sulphur or phosphorus, and always taking the form of cells or fibres, never of crystals,—and building up the organised frame; the other set rejecting those adventitious matters, tending always to the crystalline forms, and to the same mode of combination of the elements as takes place, under the same temperature, where no living structures exist,—and which are always expelled from the organised frame. These are facts of such obvious importance, so generally observed and characteristic, that the physiologist cannot decline to take cognizance of them, and arrange them together, and have some general expression for them. It does not appear possible to express these facts otherwise than by saying, that the particles of these elements taken into living bodies, are under the influence of different chemical laws at different times; which is exactly what we mean by saying, that they are first actuated by vital affinities (called vital because they are seen only in living structures, and in connection with the indications of life), by which the organised structure is gradually formed, and afterwards by simply chemical affinities by which it is gradually worn down; and that both are in continual operation during life. And thus it appears that the chemical change, which always attends the absorption, and discharge by the excretions, of all parts of a living body, is simply this,—that they lose their vital properties, and become liable to the same affinities among themselves, and the same action with the oxygen brought to them by the blood, as prevail in the dead state.

This inference as to the loss of vital properties, has been stated by several authors of late years, in regard to those portions of the living solids which perform distinctly vital actions in a visible or tangible form, as the portions of muscular fibre or nervous matter, which are employed in vital motions and sensations; but as the facts from which we draw the inference are equally true of bones and membranes, and other animal solids, unconcerned in any such vital actions, it seems to me necessary to extend the inference to all those portions of matter which exhibit in a living body the vital affinities, as well as to those which take on any kind of vital movement, or are concerned in any nervous actions.

That oxygen must be the main agent in effecting the changes of these animal compounds, which precede their expulsion in the excretions, is sufficiently proved by observing, *first*, that it is uniformly and necessarily applied to them when these changes are going on; *secondly*, that the compounds into which the animal

matters are converted before they are excreted, contain a much larger proportion of oxygen than those compounds themselves; and, *thirdly*, that it is also necessarily applied to all dead animal matter when the decomposition, leading to the same ultimate results, takes place in it.

It is true that the Bile does not contain a larger proportion of oxygen than albumen, but it contains a larger proportion than any kind of oil or fat, from which it appears certain that it is partly formed; and, farther, we have perfectly good evidence, very well stated by LIEBIG, that by far the greater part of the bile in all animals, and nearly the whole in the carnivora, is re-absorbed into the blood, and exposed gradually to the action of oxygen on it above indicated, and therefore that the secretion of the liver, so far as it is destined to excretion, resolves itself chiefly into the excretion of carbonic acid and water by the skin and lungs, and partially also into that of urea and uric acid by the kidneys; which arrangement, we have reason to believe, is designed with a view to the maintenance of animal heat, to be considered afterwards.

It may here be a question, whether the simply chemical attraction of the oxygen, carried to the extremities of the vessels in the blood, is the cause, or part of the cause, of the act of absorption, antagonizing the strictly vital attraction by which the elements of nutrition are brought into the cells of the textures. But the power exercised by the excretory glands themselves appears manifestly to be merely that of selection and attraction of the material destined to pass out by them, by an agency of cells quite analogous to that by which the cells of the textures appropriate their own nourishment; and by this simple and beautiful principle, of certain cells, or the cells in a certain part of the structure, exerting a peculiar attraction for certain matters only, existing in the compound fluid presented to them, nature has provided both for the nutrition and growth of all the textures, and for the expulsion of such matters as must be evolved from the blood, and have not such a property of volatility as might enable them to pass off by the skin and lungs.

It may be objected to the statement now made as to the respective provinces of vital and simply chemical affinities, that vegetable and animal substances removed from the living structures which formed them, are often of long and nearly indefinite duration; but it would be an error to infer from this fact, that the affinities which led to their formation act as long as they endure; we can only infer that the conditions, under which other chemical affinities act on such compounds, are not present; and the general property of the inertia of matter prevents their changing the condition into which they have been once brought, just as the same substance reduced to the state of charcoal may remain long unaltered, although in contact with oxygen, and liable to an affinity with that gas, which, under a slight variation of circumstances, would convert it into car-

bonic acid. "There exists," says LIEBIG, "in every compound a statical momentum (*moment statique*) of the attractive powers which combine the elements; the inertia of the elementary atoms, or their disposition to persist in the same state, or in the same place, where they actually exist, acts there as a special force. If the atoms of sugar were held together by as strong a force as the elements of sulphate of potass, they would suffer as little disturbance as these, from the presence of a ferment or a putrescent body. But this is not the case. The elements of all organic compounds which are capable of undergoing transformations preserve their condition only in virtue of the *inertia*, which is one of their properties."\*

Again, it has been reasonably objected to the doctrine of the nutrition and growth of animals being due to an affinity between their textures and the ingesta taken into them, which ceases when these ingesta lose their vitality, that these aliments are very generally in a dead state before they are submitted to the organs of digestion.† But I apprehend the proper answer to this to be, that,—so far as the chemical phenomena of life are concerned, the death of an entire living structure is quite distinct from the death of any one of its component parts. The whole of a living structure dies when its nutrition, the most essential of its functions, is brought to a stand by the failure of circulation; but the organic compounds, formed, as I believe, by vital affinities in that structure, remain for very various periods of time unaltered, or are preserved, as LIEBIG expresses it, by the inertia of matter, from forming those inorganic compounds to which they are ultimately destined; and as long as they remain *fresh*, or, although undergoing decomposition, have not yet reverted to those inorganic compounds, they seem to be still capable of being acted on by the vital affinities of animals. But, when the simply chemical affinities have really resumed their power, when a part of the body has undergone a certain degree of putrefaction,—when the carbon of these compounds has passed into the state of carbonic acid,—or even when this and the other elements have combined so as to form the excretions, which are steps in the process by which they revert to carbonic acid, water, and ammonia,—they are no longer capable of being applied to the nutrition of animal bodies, until they have been again subjected to the influence of vegetable life. The fact of their falling into the combinations which form the excretions, in the act of absorption from the living textures, must be regarded as proof that they have lost their own living properties, and can no longer form part of a living texture, although still within a living structure. This death of the individual molecules forming the living textures, I take to be the counterpart of the continued nutrition of those textures during life, as a general fact in the history of

\* "Sur les Phenomenes de la Fermentation," &c. *Annales de Chimie*, t. lxxi., p. 19, 193.

† See the Review of PROUT's 4th edition, in *British and Foreign Review*.

living animals. It is by thus losing their vitality that these molecules become liable to the interstitial absorption (of HUNTER); and their places are taken by fresh molecules by virtue of the vital attraction which constitutes nutrition.

It appears certain also, that the healthy exercise of the vital functions of any texture (although within certain limits it strengthens all the vital properties, and augments the living structure, apparently by attracting an increased flow of blood) determines the more speedy death of the molecules composing it, and the more rapid change of its particles by absorption. This may be expressed by saying, that this mode of vital action, as well as all muscular and nervous action, is subject to the general law of alternate increase and diminution. Hence the increase of absorption, and therefore of the excretions from exercise, even when all ingesta have ceased. And hence, also, if the vital act of nutrition in any texture is morbidly excited, as happens in every case of inflammation tending to the formation of plastic lymph, we have subsequently an increased loss of vitality in the molecules of that part; and therefore, either the formation of purulent matter destined to excretion, or the increased absorption of the newly formed or effused lymph, or the ulcerative absorption of the solids previously existing, or sloughing, or gangrene,—all well-known results of the inflammation, but which have not been duly regarded as all implying more or less partial *loss of vitality*, and therefore dependent on the same principle; and which experience shews to be linked together and even to graduate into one another.

In like manner the progressive absorption of HUNTER is probably to be ascribed to the influence of pressure, injuring and permanently destroying the vitality of parts not intended nor fitted to undergo pressure, and thereby preparing them for absorption and for the action of oxygen.

It is hardly necessary to add to this statement, after the researches of DULONG and DESPRETZ, of DUMAS and of LIEBIG, that the combination of oxygen with the other constituents of the excretions, and particularly with the carbon and hydrogen, is (as has always been maintained by most physiologists in this country) the true cause of Animal Heat; and it cannot be doubted that one of the uses of the aliments, especially the non-azotised aliments, continually taken into the body, is merely to enter into this combination, and fulfil this purpose. But there is one principle on this subject, not so generally recognised, but which the observations of LIEBIG, and likewise of SCHERER, of PETTENHOFFER, and of BOUCHARDAT and SANDRAS,\* seem to make nearly certain, viz., that a principal use of the secretion of the Liver (*i. e.* of the animal matter there secreted) is, to serve as a reservoir for the most easily combustible matter which is taken into the primæ viæ; so that,—just as the chyme of the stomach and intestines furnish a pretty constant supply of nourishment from occasional supplies of aliment,—

\* See PAGET's Report in FORBES's Journal, April 1846, pp. 561 and 562.

so the Bile from the liver, likewise reabsorbed as it passes down the *primæ viæ*, furnishes to the blood a pretty constant supply of matter fit for calorific combination with oxygen, out of the occasional ingesta.

The proofs of this proposition, and its importance, appear from the following facts, ascertained by these authors. 1. That by far the greater part of the amylaceous matter taken into the stomach, is converted into soluble matter (dextrine and sugar) in the *primæ viæ*, and these must necessarily be absorbed by the veins, and of course carried to the *vena portæ* and liver. From thence a part of this matter, no doubt, will pass immediately by the *venæ cavæ hepaticæ* to the right side of the heart and lungs, and come immediately into contact with the oxygen; but a part, meeting a portion of effete animal matter in the venous blood will aid in the formation of bile in this way:

	C	N	H	O
4 equivalents of starch	48	...	40	40
Add 1 of ammonia	...	1	3	...
	48	1	43	40
Subtract elements of choleic acid	38	1	33	11
	10	...	10	29

requiring only one part of oxygen to pass into  $10\text{ CO}_2 + 10\text{ HO}$ , carbonic acid and water; which accounts for the great quantity of bile secreted by herbivorous animals; and accounts likewise for the secretion of bile being chiefly from venous blood, inasmuch as very little oxygen is required for its formation, and its chief pabulum has been recently absorbed by the veins. In so far as bile is formed from fat, it must be by help of more oxygen, and, therefore, probably from arterial blood.

2. That of the bile formed and discharged into the intestines, the greater part, even in the herbivora, and almost the whole in the carnivora, is reabsorbed into the blood, and decomposed in the process, the pure bile appearing distinctly in the faeces almost exclusively in the case either of diarrhoea, or of the operation of cathartics. When to these facts we add these considerations, that biliary matter retained in the blood, as in one form of jaundice, acts as a poison, and that it cannot be of use in the nutrition of the textures, which is provided for by the albuminous contents of the blood, we can hardly doubt that it is reabsorbed into the blood, only that it (or its elements) may unite with oxygen, and be thrown off as carbonic acid and water, with a little urea; and therefore, that the liver is an appendage to the digestive organs, destined for the proper disposal of the calorific, rather than the nutritious portions of the food, and for the necessary separation of these two; and that the circulation of the matter destined to this

ultimate object, through the liver, answers the important purpose of equalizing the quantity of matter in the blood, which is always ready for this calorific union with oxygen.

This doctrine, as to the chief use of the animal matter of the bile, appears to correspond perfectly with several known and important facts. When the quantity of bile thrown off by the liver, and discharged by the bowels, is decidedly greater than usual, the animal heat is remarkably depressed, as in cholera, apparently because the quantity reabsorbed and applied to the evolution of heat, is diminished. In herbivorous animals, the quantity of bile discharged from the bowels is much greater than in the carnivorous, because the quantity of amylaceous matter which they consume is so much greater, that a much larger quantity is secreted, and if all reabsorbed into the blood, it would cause a morbid increase of heat. Again, in warm climates and seasons, the formation of bile is apparently stimulated, the liver is excited to increased action, and there is such an increase of the discharge by the bowels, as serves to lessen the quantity of combustible matter in the blood, and keep down the temperature of the body; but then this increased stimulation of the liver renders it more liable to various forms of disease.

When we say that oxygen, acting on the redundant, on the non-azotised, and on the effete matters with which it meets in the blood, is the main agent in forming the excretions, and causing the waste of the body, we use language which is, to a certain degree, ambiguous. It seems to me that the oxygen is probably capable of acting on all the matters in the blood for which there is no strong vital affinity in the body; and that the action of the oxygen on the matters which are ready to be, or have been, absorbed from the textures, is rather the consequence, than the cause, of their having lost their vital properties, and thereby come under the dominion of ordinary chemical affinities. The oxygen is, no doubt, the agent by which the gradual extenuation of the body, in death by famine, or by many lingering diseases, is effected, but this agency of the oxygen is in itself salutary, and even necessary to life; the real cause of death is, that cause which prevents the loss of substance effected by the oxygen from being immediately repaired, *i. e.*, it is the deficiency of nourishment, to take the place of those portions of the textures which have lost their vital properties, and therefore come under the dominion of the oxygen.

This seems to be confirmed by the fact which appears to have been fully ascertained by CHOSSAT, that the rate of waste, *i. e.*, the rapidity of absorption of the textures of the body, is greatest shortly before death, *i. e.*, when the supply of the oxygen must be diminished, rather than increased, from the state of the circulation and respiration,—but when the vital powers, and especially the vital affinities, are losing their power, and the supply of nourishing matter has ceased. This fact alone seems sufficient to shew that the absorption, which is constantly

going on in the textures while life continues, is due to the partial loss of vital power of these textures themselves, and is the cause, rather than the consequence, of the agency of oxygen upon them.

When we consider, farther, how exactly this is in conformity with the general fact, that all other kinds of vital action are *essentially temporary*,—that all nervous actions, and all muscular contractions, necessarily alternate with periods of repose,—I think we can have no difficulty in acquiescing in the general law of all Vital Affinities, at least so far as animals are concerned, which explains at once the necessity of constant nutrition of all animal bodies (even when their weight is stationary or declining), the principle of interstitial absorption, the use of respiration, the maintenance of animal heat, and the necessity and nature of the excretions; viz., that as the perpetuation of each species is provided for only by the successive life and death of numberless individuals, so *the life of each individual is sustained only by the successive life and death of all the portions of matter of which its body is composed*; and that each portion, as it dies, falls under the power of the oxygen absorbed from the atmosphere, as it would do in the dead body, and enters into new combinations which are injurious to the living system, but pass off by the excretions; gradually reverting to those inorganic compounds, from which the power of vegetable life only can again raise them to the condition of organized and living matter.

The general conclusions regarding Vital Affinity, which seem to me to be warranted by this review of the subject, and to be sufficiently established to be stated as principles in Physiology, are the following:—

1. That it is by a power peculiar to the state of life, and equally vital as the irritability of muscles, but varying in the different parts of each organized structure, that the solids, and especially the cells of organized matter, attract, select, consolidate, and arrange in their substance, and within their cavities, certain substances, usually compound, which are brought into contact with them, and reject or exclude others.

2. That in the cells of organized matter, during the living state, and apparently by an influence of these cells analogous to that chemical influence to which the term Catalysis has been applied, analogous also to fermentation, certain definite transformations of chemical elements take place, which are equally peculiar to the state of life; which transformations, at least in animals, appear to be effected more in the cells or corpuscles which float in the fluids, than in those which compose the solid part of the structure.

3. That although we have proof that the origin of all the organized beings now seen on the earth's surface has been of recent date, in comparison with the earth itself, we see these powers, thus exercised, continually transmitted to successive sets of cells in each individual, and to successive generations of individuals, with-

out being able to remount to the origin of this kind of action in this, as in others of the sciences lately called palætiological.

4. That the first essential condition necessary for the development of all organized life, is that vital affinity by which, under the influence of light, the cells of vegetables appropriate and decompose the carbonic acid of the atmosphere, fix the carbon, and attach to it the elements of water, so as to form amylaceous matter.

5. That the ulterior changes, effected within organized structures, by which oily, albuminous, gelatinous, and perhaps extractive compounds, are formed and assimilated to the living textures, appear to belong to certain definite vital affinities of the carbon, originally fixed from the air, and which is the basis of all organized substances, not only for the elements of water, but for hydrogen, for azote, for sulphur, phosphorus, and various salts; that most or all these ulterior changes are effected both in vegetables and animals; and that the oxygen taken in by the organs of respiration, although it may be necessary to the play of all the different affinities in living bodies, appears hardly to enter, if it enter at all, into the constitution of any of the compounds thus formed and applied to the nourishment of the textures.

6. That these compounds, in order that they may be applied to this purpose, must be moved within living bodies, and applied, in the fluid form, to the textures which they are to nourish, although in various instances, both in vegetable and animal life, they have themselves the solid form; and that the requisite fluidity is given by various contrivances, chiefly seen in the *prima vie* of animals,—by mechanical attrition, by incipient decomposition of the materials employed, but especially by a simply chemical solution of these,—for which purpose certain parts of living structures are endowed with a vital power of separating acids, and others of separating alkalies out of the compound fluids pervading them, and thus preparing solvents for those solids.

7. That the vital affinities do not, strictly speaking, supersede ordinary chemical affinities in the living animal body, but are superadded to them, so that the ingesta, as they come under their influence, are divided between the combinations to which those different kinds of affinity dispose them, and particularly are partly under the influence of the substances exerting vital affinities, and partly of the oxygen of the air, brought to them by the arterial blood; and that as these ingesta often contain large quantities of matter, especially of non-azotised matter, either inapplicable to the formation of the animal compounds, or redundant, these portions, fall immediately under the influence of the oxygen, and form one source of the excretions from the animal body.

8. That the vital affinities, like all living properties, are liable to an influence of *place* and of *time*, which is not seen in the inorganic world, but is an essential attribute of the organized Creation, which has been superadded, in later times, to the original arrangements of the universe. They are acquired by por-

tions of matter which are brought to particular points in previously existing organized structures ; they are vigorous for a time, and are then lost. In all the compounds constituting the animal textures, these affinities become gradually enfeebled, whereby the elements constituting these textures become liable to absorption into the blood, to changes in their arrangements, chiefly effected by the oxygen of the air, to combinations with the redundant matters above noticed, and to the formation of other compounds in the blood, which are either the same as, or rapidly tend to, the combinations with oxygen to which animal matter is liable in the dead state ; which are, therefore, properly speaking, due to simply chemical affinities, and therefore crystallizable, like other inorganic compounds, and are noxious to the animal economy. This is another source of the excretions, for the separation of which appropriate organs are furnished, capable by their vital power of absorbing and abstracting them from the blood.

9. That the simply chemical power thus exerted by the oxygen, taken in by respiration, over the redundant (especially non-azotised) matter in the blood, and the *effete* matter of the textures, is the source of Animal Heat.

10. That there is thus effected during the life of animals, but in consequence of the failure of their vital affinities, and restoration of the simply chemical relations of their component elements, a change equivalent to the slow combustion of the organized matter, which had been first prepared by the vital affinities of vegetables ; and that the carbon, hydrogen, and other elements employed in the formation of that matter, are thus continually resuming that condition, from which the power of vegetable life is continually abstracting them again, to communicate to them a set of properties at variance with those which they permanently possess ; and apply them to a succession of organized beings which can only terminate, as at no very distant period of time it must have originated, by an arbitrary act of Divine power.

The gradual change both in vegetable and animal structures which results from age,—the increase of the proportion of earthy and saline matter, and diminution of the proportion of strictly organic matter,—must be regarded as indicating a peculiarity of the vital affinities equally an ultimate fact as their limited duration in every portion of a living body. And the modification to which these affinities, as well as all other strictly vital powers, are liable in animals, from certain actions of the nervous system, must likewise be regarded as an ultimate fact, quite distinct from any principles that have been ascertained in regard to the nature of the vital affinities themselves.

On reviewing the statements and reasonings which I have laid before the Society on the subject of Vital Affinity, although I may have committed errors in the details, I cannot accuse myself of having occupied their time, either with a vague and useless speculation, or with a verbal dispute.

That there is *something* in the history of all living bodies which is *peculiar* to

them, at variance with the laws that regulate the changes of inorganic matter, and requiring to be investigated by a separate induction of facts, must be admitted by all; and is indeed the only reason we can give for treating Physiology, and the branches of knowledge dependent on it, as a separate science; and this being so, it belongs to the very elements of the science to determine what are the portions of the history of living bodies which come under this category.

I have always held in high respect the aphorism of HEBERDEN, which Dr GREGORY used to recommend to the special attention of his pupils, that the great desideratum in medical science is the detection of the Vital Principle, by which all that goes on in the living body is regulated and governed; but I have always thought likewise, that the object of this investigation is rightly limited by Dr PROUT, when he says that we should inquire, "not what the vital principle or vital power *is*, but what it *does*." In fact, in all the sciences, we can acknowledge only one principle and one Power, as the origin of all the phenomena that we investigate; and when we use these terms in reference to living beings,—when we say that we inquire how the vital principle acts,—we use the term only as a convenient and simple expression for an investigation of the laws according to which the Divine power acts, in regulating the changes which are continually taking place in the last and noblest of the works of creation, and which differ from the changes that we see around us in other departments of nature.

This precise and definite object of all physiological researches—the determination of the laws that are *peculiar* to the science—has always attracted the attention of physiologists, but has not always been placed in the proper point of view; and the common error in this, as in other sciences, has been, to regard the laws of nature as simpler than they really are, and to stretch a principle, ascertained as to one set of phenomena, in the hope that it would be found sufficient to embrace many more. Thus it was easily observed that the phenomena of sensation and thought, and the visible motions in animals, were quite peculiar to them; and when it was ascertained that the first of these, and that a large portion of the latter (viz., all voluntary motions), depend on the living state of the nervous system, it was hastily concluded that all the phenomena peculiar to animal bodies, depend on their Nervous System. This is illustrated by the title of one of the chapters in GREGORY's "Conspectus." "De solido vivo, seu genere nervoso," as if there were no living property in any of the animal solids but what is given to them by the nervous system; or, by the explicit declaration of CULLEN, that he considered the vital principle as "lodged in the nervous system."

The progress of the science has, I think, distinctly shewn that these ideas, as to the parts of the animal economy in which the peculiar laws of vitality operate, were limited and erroneous; although physiologists (trained in the schools of medicine where the authority of these and other teachers, adopting similar doctrines, has been held in just veneration) have been generally reluctant to admit the error.

I have endeavoured, in papers laid at different times before this Society, to

limit and define our notions of the powers exercised by the Nervous System, in producing the phenomena of the life of animals, maintaining on that subject the different parts of one general and fundamental proposition ; viz., that there is no good evidence, and that in the absence of such evidence it is unphilosophical to assume, that any changes in the nervous system are essentially concerned in producing any phenomena in the healthy state of the system, except those in which *some mental act is necessarily involved* ; but that all the powers which are exercised, in the natural and healthy state, by the nervous system, in a living body, are those by which it fulfils its destined office as the seat, and the instrument, of mental acts,—of Sensation, Thought, and Instinctive or Voluntary effort ; and that the nature of these powers, and the uses or intention of the different parts, and of all the arrangements of the nervous system, if judged of simply in reference to these, the specific objects of its creation, are tolerably well ascertained ; vindicating, at the same time, the doctrine of HALLER, in regard to the separate vital property of Irritability or Contractility in muscles, and its different modes of connection with the nervous system.

I likewise stated, on a former occasion, to this Society the evidence of another fundamental principle in physiology—of the existence and the chief agencies of a power exercised by living bodies, and peculiar to their living state—which is capable of producing motion, or of influencing motion otherwise produced, but which acts in the way of Attraction and Repulsion ; and is, therefore, quite distinct from that living power of animal solids, acting in the way of contraction and impulse, which is well understood ; and to which, since the time of HALLER, the name of Irritability, or the more general term Contractility, has been applied.

Although both these principles have been strongly contested, I have had the satisfaction of seeing them adopted, and their importance acknowledged, by most of those who have prosecuted the science of Physiology in this country of late years, with the greatest diligence and success. I have now laid before the Society the general grounds of a third opinion, which I hold to be of equal rank in physiology ; viz., that there are laws, peculiar to living bodies, acting to a limited extent only, and already in a considerable degree ascertained, which alter and control the ordinary chemical Affinities of the matter composing those bodies, as distinctly as the laws of muscular contraction, or of vital attractions and repulsions, modify the effects of the ordinary mechanical properties of matter within them. And if this doctrine shall, as I confidently expect, be equally admitted to be correct, then, although laying claim to no credit as a discoverer, I hope I may be allowed the satisfaction of reflecting, that I have contributed somewhat towards fixing the foundations of the noble science of Physiology ; and establishing those principles in that science, to which continual reference must necessarily be made, in any speculations to which we can apply the epithet scientific, in regard either to the nature of diseases or the operation of remedies.









































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